SARS-CoV-2 seroprevalence and respiratory disease disability claims in Mexico City Metropolitan Area

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Abstract

Objective. To characterize the impact of SARS-CoV-2 infection in workers from an essential large-scale company in the Greater Mexico City Metropolitan Area using point prevalence of acute infection, point prevalence of past infection through serum antibodies and respiratory disease short-term disability claims (RD-STDC). **Materials and methods.** Four randomized surveys, three during 2020 before and one after (December 2021) vaccines' availability. Outcomes: point prevalence of acute infection through saliva PCR (polymerase chain reaction) testing, point prevalence of past infection through serum antibodies against Covid-19, RD-STDC and prevalence of symptoms during the previous six months. **Results.** Prevalence of SARS-CoV-2 cases was 1.29-4.88%, on average, a quarter of participants pre-vaccination were seropositive; over half of participants with a RD-STDC had antibodies. The odds of having antibodies were 6-7 times more among workers with an RD-STDC. **Conclusions.**

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Resumen

Objetivo. Caracterizar el impacto de la infección por SARS-CoV-2 en trabajadores de una gran empresa esencial del Área Metropolitana de la Ciudad de México, utilizando prevalencia puntual de infección aguda, prevalencia puntual de infección pasada a través de anticuerpos séricos e incapacidades temporales para el trabajo por enfermedad respiratoria (ITT-ER). **Material y métodos.** Cuatro encuestas aleatorias, tres durante 2020 y una en 2021, sobre de disponibilidad de vacunas. Desenlaces: prevalencia puntual de infección aguda a través de pruebas de PCR (*polymerase chain reaction*, por sus siglas en inglés) en saliva, prevalencia puntual de infección pasada a través de anticuerpos séricos contra Covid-19 (niveles de anticuerpos S/N), ITT-ERs y prevalencia de síntomas durante los seis meses anteriores. **Resultados.** La prevalencia de casos positivos para SARS-CoV-2 fue de 1.29-4.88% y, en promedio, la cuarta parte de participantes presentó anticuerpos prevacunación; más de

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High antibody levels against Covid-19 in this study population reflects that coverage is high among workers in this industry. STDCs are a useful tool to track workplace epidemics.

Keywords: SARS-CoV-2 seroprevalence; short term disability claims; essential workers; Mexico

la mitad de participantes con ITT-ER tenían anticuerpos. Las posibilidades de tener anticuerpos fueron 6-7 veces mayores entre aquellos con ITT-ER. **Conclusiones.** Los altos niveles de anticuerpos contra el Covid-19 en la población de estudio reflejan que la cobertura es alta entre los trabajadores de esta industria. Las ITTs son una herramienta útil para rastrear epidemias en el lugar de trabajo.

Palabras clave: seroprevalencia de SARS-CoV-2; incapacidad temporal para el trabajo; trabajadores esenciales; México

Essential workers outside of the healthcare sector have had an important role in maintaining the core functions needed for the economy and society during the Covid-19 pandemic. However, many were more vulnerable to infection because they worked in riskier conditions (such as customer-facing roles, production lines where employees work close together; physically intense and high-speed labor), used public transportation, and had less access to information regarding measures to prevent infection.[1] Furthermore, despite this increased risk, these groups were not a target for early vaccination in many countries. After vaccinating health professionals, the Mexican Government used an age-descending order to prioritize the national vaccination rollout plan,[2,3] to protect those who are at most risk of death, and the limited supply of vaccines drove the government to ignore the prioritization of other essential workers.[4,5]

Mexican private-sector workers and their families receive healthcare (in primary care clinics and hospitals nationwide) and economic benefits (short-term disability support, pension funds, day care support, etc.) from the Mexican Social Security Institute (IMSS, in Spanish). IMSS covers over 20 million workers plus their families, translating to almost half of the Mexican population, and is tasked with ensuring workplace safety and continuity, preventing outbreaks, maintaining essential activities, and protecting employment and workers' livelihoods.[6] Throughout the pandemic, IMSS worked closely with private-sector industries to provide simple and actionable methodologies to monitor and respond to Covid-19 in the workplace, helped operationalize economic reactivation guidelines and requirements, and was pivotal in the vaccination efforts.[7] We have previously reported on using respiratory disease short-term disability claims (RD-STDCs) to track Covid-19 in IMSS-affiliated workers,[8,9] however there are no studies that analyze these administrative data in combination with antibody measurements among workers from essential industries other than the health sector.

A limited number of studies have focused on non-healthcare essential workers and how SARS-CoV-2 seroprevalence evolved previous to the vaccine roll-out.[10-12] Additionally, disease incidence in this population can be tracked using short-term disability claims (STDCs) submitted to IMSS. The aim of this study was to characterize the impact of SARS-CoV-2 infection in workers from an essential large-scale company in the Greater Mexico City Metropolitan Area using point prevalence of acute infection, point prevalence of past infection through serum antibodies and RD-STDC.

Materials and methods

We conducted four cross-sectional surveys of IMSS-affiliated workers from 38 work centers of an essential large-scale company in the GMCMA: September 22-29, 2020, November 9-13, 2020, January 4-9, 2021, and November 22-26, 2021. To obtain a representative sample, we used an anonymized list and a stratified random sample (SRS)[13] controlled by work center category (sales center, production plant, and distribution center). Sample allocation was proportional to the work center size during the corresponding cycle. Eligible study participants included those working in person, therefore available during study testing days. All participants reported being in good health and free of any Covid-19 symptoms at the time of the survey. Personnel with comorbidities were working remotely as per mandate of the Health Ministry and the company. Cycle 1 had a sampling frame of N_1=10 419, of which n_1=965 was randomly selected; Cycle 2: N_2=9 358, with n_2=1 195 selected; Cycle 3: N_3= 10 966, with n_3=760 selected; and Cycle 4: N_4=11 602, with n_4=1 011 selected. Due to financial reasons the company decided that for Cycles 2 and 3, participants who had previously tested positive for antibodies were excluded from the sampling frame. Only study participants with a blood sample had antibody testing, therefore individuals recruited for cycle 2 that were not included in cycle 1 (and those included in cycle 3 that were not included in cycle 1 or 2) didn't have antibody testing. In order to be excluded from the sampling frame a worker had to participate in a previous cycle and test positive for antibodies, those testing negative could be randomly selected to the next cycle, given that they were still working for the company (Cycle 2: 8 repeated, Cycle 3: 45 repeated, Cycle 4: 110 repeated). Additionally, on study visit days at the work centers, workers who were not randomly selected through the sampling frame but who wished to participate were included in a convenience sample. These results were analyzed separately from the randomized representative sample and are reported separately and weighted by work center category (sales center, production plant, and distribution center).

A signed informed consent was obtained from all participants. The National Scientific Research Committee at IMSS approved this research protocol (R-2020-785-065).

Biological samples

We measured the total antibodies against the nucleocapsid protein and receptor-binding domain of the spike protein. We used chemiluminescent microparticle immunoassays to determine the presence of antibodies to SARS-CoV-2; for Cycles 1-3, to detect IgG type immunoglobulins against the SARS-CoV-2 nucleocapsid (Anti-N) virus, we used the AdviseDx SARS-CoV-2 IgG II assay on the Abbott Laboratories' ARCHITECT i1000SR.[14,15] For Cycle 4, we used Roche's Elecsys Anti-SARS-CoV-2 S immunoassay on the COBAS e411, which evaluates the presence of antibodies to the spike (S) protein.[16]

SARS-CoV-2 infection was determined Covid-19 presence was assessed via reverse transcription polymerase chain reaction (RT-PCR). Saliva was collected in 50 ml polypropylene wide-top, twistable-lid tubes (8-10 ml) by passive drooling; nucleic acids were extracted from 200 µL of saliva using the viral/pathogen nucleic acid isolation kit MagMAX (Thermo Fisher Scientific). We eluted 75 µL in the elution buffer and used the RT-PCR kit TaqPath Covid-19 CE-IVD.[17] The kit detects the genes ORF1ab, S protein, and N protein. We classified samples as positive when primer/probe sets with a cycle threshold value (Ct) less than 40 were detected. If only one of the genes was detected, the sample was classified as inconclusive. All tests were detected with real-time thermocyclers ABI QuantStudio 5 or QuantStudio 7 from Thermo Fisher Scientific. Blood and saliva samples were collected before noon and transported daily to the Mexican Institute of Genomic Medicine (Inmegen, in Spanish) for analyses. We obtained information for participants Social Security number (SSN), sex and age at the time we collected the samples.

Questionnaire

Participants were asked to complete the sociodemographic questionnaire within two days before or after sample collection. From this, we obtained information on self-reported respiratory illness and Covid-19 symptoms (fever, headache, new or worsening cough, shortness of breath, sore throat, rhinorrhea, diarrhea, anosmia, myalgias, and conjunctivitis) since March 2020 to the date of the study visit, therefore those without questionnaire are not included in the association analysis that includes this information as a covariate.

Respiratory disease short-term disability claims (RD-STDCs)

An STDC can only be issued by a medical doctor at an IMSS facility (clinic or hospital). For workers who answered the questionnaire, we used SSN to match the antibody and PCR test results with the IMSS RD-STDC database from January 1, 2020 to the first day of each cycle's study visit. We queried the STDC database for claims with any of the following ICD-10 codes: acute respiratory diseases (J01, J04-J06, J20 and J21), influenza (J10 / J11), pneumonia (J12, J18), Covid-19 (U07.1, U07I, U07S);[8,9] we utilized records in which the diagnosis contained any word related to Covid-19. To compare between study cycles, we included any RD-STDC in the previous six months.

In order to illustrate if disease developed differently in our study population compared to their peers (i.e. essential workers from this specific company, with similar exposure scenarios) and to workers in the general population, we describe the evolution of the pandemic in our study population by comparing the RD- STDCs issued to our study participants (i.e. only from the GMCMA) to 1) the RD-STDCs issued to workers from the same company at a national level (per registered worker) in other work centers across Mexico, therefore having similar exposure scenarios and 2) to those RD- STDCs issued at the same IMSS healthcare facilities than the study population (per affiliated worker to the healthcare facility in the GMCMA), to determine if the curve evolves the same as other workers (STDC can only be issued to IMSS affiliated workers). Additionally, we extracted the number of disability days authorized, the number of subsidized days and the total amount in Mexican pesos that RD-STDC in the company for the study period (i.e. January 2020-November 2021).

Vaccination history

For the fourth cycle, we included information on self-reported vaccination history and vaccine type and matched workers' national unique identity code to the National Covid-19 Immunization Database (unvaccinated or vaccinated: doses received, dates, and vaccine brand).

Statistical analysis

Analysis was performed using Bayesian hierarchical methods. Briefly, we adapted Gelman and Carpenter's methods on stratified models to multiple cycles. Hence, for all estimators we accounted for within-strata (work centers) and withing cycle variations while also considering the temporary effect of the previous cycles via dynamic priors. As an example, the prevalence for each cycle depends upon the prevalence of the previous cycle (to account for the trend). The prevalence for each stratum in each cycle depends upon the cycle's global prevalence. Finally, if groups (within strata) are involved, values of the groups depend upon the group itself, strata, and cycle. The supplementary material provides the basic structure of model estimations and a complete description of the methodology.[18]

For the first three cycles (prevaccination), we adapted the multilevel logistic regression from Gelman and Carpenter[19] to assess the odds of seropositivity conditional on sex, age group, previous Covid-19 symptoms, and an RD-STDC in the previous six months. It also accounted for time dependency within cycles, hierarchical dependency within strata, and the survey's sampling design. This analysis was not performed for the convenience sample as we could not account for the sampling frame.

For all analysis involving antibodies or PCR we also considered the tests' corresponding sensitivity and specificity. Bayesian methodology allowed us to make informed inference even on those parameters where zero or few cases were reported. Frequentist methods to correct a test's sensitivity and specificity (such as Bendavid and collaborators),[20] fall short when the proportion of positive cases is small (prevalence smaller than the test's-one minus-specificity). The survey methodology was designed for any company that was interested in implementing it. We reached out to several companies who carried out the protocol; however, the results across companies are not comparable (different economic activity, less follow-up). Therefore, this work reports the results of the company with the longest and most complete follow-up.

Estimation of the posterior distribution was conducted using No-U-Turn Sampling[21] using Stan in the *cmdstanr* package of the R programming language.[22-24] For each parameter, we report the median of the posterior distribution and the 95% credible interval (CI), defined as the highest density interval of the posterior distribution. Seropositivity (IgG) and PCR estimates were adjusted by the tests' sensitivity and specificity using 1.00 and 0.98[17] and 0.907 and 0.98[15,16] for PCR and IgG, respectively. All estimates are weighted to account for study design and test sensitivity and specificity (if applicable); all estimates presented have the corresponding 95% credible intervals (95%CI).

Results

We studied 3 768 workers (with 3 931 observations) who represented 11 420 employee observations (sample mean 38.9 years, 83.3% men). Supplementary table I[25] shows the characteristics of participants in the four cycles (crude and weighted). On average, workers were 38.9 years old. Sales centers had more workers, and the proportion of men was four times higher than that of women. Although older workers were exhorted to remote work, the study population included a small number of 60+ workers (*n*= 8). The proportion of workers in each age group remained constant, with no statistical difference between the first and third cycles and an increase in the number of workers per center (i.e. randomized) in the fourth cycle, most likely due to the return to in-person modality work.[18]

Table I shows the crude and weighted proportion of antibodies in the study population over the four cycles by age, sex, self-reported respiratory illness, and six-month previous RD-STDC. The percentage of workers with antibodies was similar across age categories except for those 60+. Men consistently had a higher probability of antibodies (figure 1 more clearly illustrates these results by age group). The percentage of workers with a previous self-reported respiratory illness and antibodies decreased from Cycle 1 to Cycle 3. For both sexes and all other categories of self-reported illness, six-month previous RD-STDC and age categories antibodies increased to almost 100% in Cycle 4, postvaccination.

The point prevalence of active infection varied in the different cycles, reflecting RD-STDC incidence observed for the study population (table I). The prevalence of IgG seropositivity also varied by cycle, with marginal difference in the first three cycles, reaching 99% in Cycle 4 after vaccination efforts had been rolled out for groups over 18. The percentage of workers who claimed an RD-STDC in the previous six months decreased significantly, from almost 13.16% in the first cycle to 6.79% by the fourth cycle (table I).

Table I

Seroprevalence in essential workers of a large-scale company in the Greater Mexico City Metropolitan Area, March 2020-November 2021

Variable	*Cycle 1: September 22-29, 2020*			*Cycle 2: November 9-13, 2020*			*Cycle 3: January 4-9, 2021*			*Cycle 4: November 22-26, 2021*		
	Sample size	*Estimate (weighted)*	*95%CI*	*Sample size*	*Estimate (weighted)*	*95%CI*	*Sample size*	*Estimate (weighted)*	*95%CI*	*Sample size*	*Estimate (weighted)*	*95%CI*
Men	831	28.51	24.59,32.21	965	22.18	18.54,25.30	642	21.26	17.38,25.20	838	99.49	98.93,99.90
Women	134	20.85	11.09,30.00	230	16.85	10.88,24.74	118	16.93	8.30,25.80	173	98.47	96.46,99.86
Under 35	322	24.61	19.00,29.82	379	18.87	13.99,23.89	213	21.40	14.55,28.05	314	98.85	97.46,99.80
35-44	312	26.89	21.58,33.42	355	22.28	16.58,27.95	248	21.60	15.00,27.85	352	98.77	97.58,99.72
45-59	220	29.07	20.95,36.70	252	18.87	12.47,24.63	194	15.99	9.38,22.40	340	99.20	98.04,99.87
60+	1	49.82	10.28,86.98	2	31.54	3.37,68.83	0	50.31	12.73,88.60	5	71.95	35.90,96.62
Self-reported respiratory illness*	255	53.61	46.58,59.65	275	38.00	31.43,44.23	208	30.19	23.34,37.09	294	99.02	97.69,99.87
No self-reported respiratory illness*	571	14.47	10.81,18.42	676	11.90	8.62,15.61	431	15.08	10.09,19.26	413	99.06	97.86,99.89
No RD-STDC in the previous 6 months	847	20.82	17.31,24.27	1 070	17.70	14.77,20.78	687	16.96	13.20,20.33	944	99.60	99.09,99.94
RD-STDC in the previous 6 months	118	68.95	60.00,77.88	125	46.00	36.24,55.88	73	51.63	38.91,64.14	67	96.31	91.57,99.37

95%CI: 95% Credible Intervals
RD-STDC: Respiratory disease-short term disability claim
* This information was obtained with a questionnaire, some study participants had this missing
Cycles 1, 2, and 3: seropositivity is for anti-N antibodies and for cycle 4, anti-S antibodies

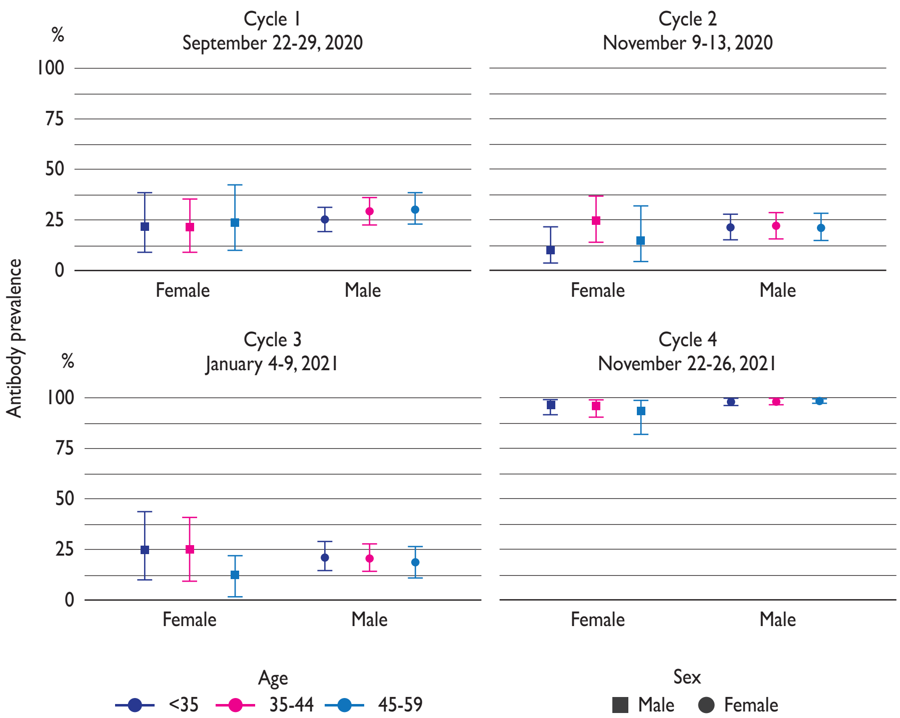

Figure 1. SARS-CoV-2 antibody prevalence by sex and age category, per survey cycle. Analysis adjusted by test specificity (0.98) and sensitivity (0.907)

Figure 2 shows the inferred evolution of RD-STDC incidence, since the beginning of the pandemic (prevaccination)-including the national *Jornada Nacional de Sana Distancia,* a period of voluntary lockdown for nonessential workers from March 23 to May 31 of 2020[26] -until the postvaccination period in November 2021. The RD-STDC incidence in our study population mimicked that of the rest of the company and was slightly above that within the same IMSS healthcare facilities. In terms of the economic impact, these RD-STDC represented 119 210 authorized disability days of which 86 848 were subsidized, translating to 43 061 788 Mexican pesos. The prevalence of workers with antibodies is shown for each study cycle with respect to the vaccination campaign rollout: below 28% for the first three cycles, sharply increasing to 99.6% by November 2021.

Table II shows that the odds of seropositivity were higher for men than women and almost sixfold during Cycle 3 (OR: 6.66; 95%CI: 2.58,26.82). Compared to workers younger than 35, those 35-59 had higher odds of seroprevalence in all cycles and these were statistically significant for age group 35-44 in the second cycle and for age group 45-59 in cycles 1 and 2. Workers 45-59 had three times the odds of seropositivity compared to the youngest workers in Cycle 2 (OR: 3.40; 95%CI: 1.72,7.15). For Cycle 1, workers with self-reported previous Covid symptoms had seven times the odds of seroprevalence compared to those without such symptoms (OR: 7.51; 95%CI: 4.24,14.02). The odds of seroprevalence were higher for those workers with a previous RD-STDC compared to those without and highest for Cycle 2 (OR: 7.28; 95%CI: 3.76,15.07).

Vaccination status

Table III shows the percentage of workers vaccinated and with antibodies within each vaccine group; 98.26% were vaccinated. AZD1222 was the most widely used vaccine, accounting for 52.48% of the population, followed by Gam-COVID-Vac (18.36%), CoronaVac (6.38%), BNT12b2 (3.96%), mRNA-1273 (2.49%), Ad5-nCoV (0.49%), and Ad26.COV2.S (0.36%). We were unable to identify brand for 13.39% of the study population. In vaccinated individuals (at least one dose), the proportion of antibodies by vaccine type was higher than 90%, except in Ad5-nCoV and Ad26.COV2.S, for which the sample size was too small (*n*= 2 and *n*= 1, respectively).

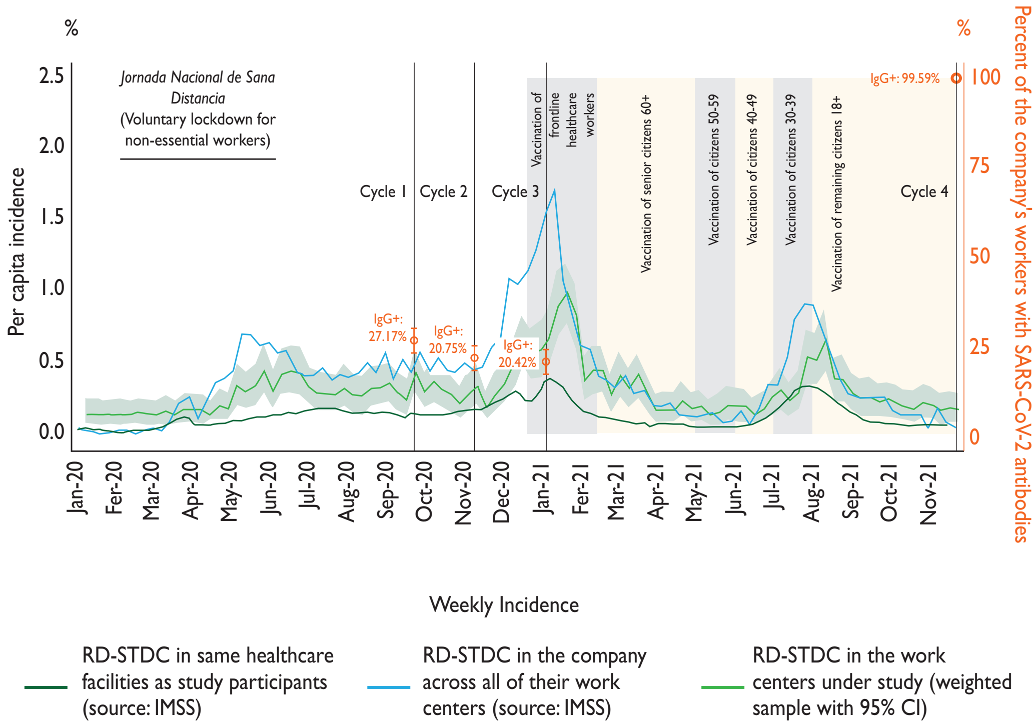

Figure 2. Estimated weighted incidence per epidemiological week of respiratory disease short-term disability claims (RD-STDC) among essential workers of a large-scale company in the Greater Mexico City Area (study population), workers of the entire company and of the same healthcare facilities used by the study population

Table II
Association between sex, age group, Covid-19 symptoms, and respiratory disease short-term disability claim (RD-STDC) and seroprevalence among essential workers of a large-scale company in the Greater Mexico City Metropolitan Area, March 2020-November 2021

Variable	*Cycle 1*		*Cycle 2*		*Cycle 3*	
	OR	*95%CI*	*OR*	*95%CI*	*OR*	*95%CI*
Men	3.82	1.99,8.00	3.45	1.73,7.70	6.66	2.58,26.82
Age group*						
35-44	1.53	0.79,3.05	2.43	1.24,4.91	1.66	0.76,3.64
45-59	2.67	1.44,5.47	3.40	1.72,7.15	1.90	0.83,4.19
60+	0.84	0.07,9.29	0.71	0.02,13.80	0.76	0.01,37.61
Presence of Covid-19 symptoms						
Covid-19 symptoms	7.51	4.24,14.02	3.84	2.07,7.31	3.31	1.63,6.94
RD-STDC (in the previous 6 months)	6.44	3.24,13.67	7.28	3.76,15.07	5.72	2.72,12.00

95%CI: 95% Credible Intervals
* Reference group: younger than 35 years old

Table III
Vaccination status and seroprevalence for each vaccine brand in essential workers of a large-scale company in the Greater Mexico City Metropolitan Area, November 2021

Vaccine	*Vaccinated workers*			*Antibodies within vaccine group*		
	Sample size (crude)	*Weighted estimate (%)*	*95%CI*	*Sample size (crude)*	*Weighted estimate (%)*	*95%CI*
Astra Zeneca	443	52.48	49.10,55.90	443	99.36	98.48,99.95
Cansino*	2	0.49	0.15,1.09	2	60.59	25.07,93.36
Janssen	1	0.36	0.07,0.79	1	51.02	12.16,88.93
Moderna	21	2.49	1.51,3.58	21	90.64	72.39,98.83
Pfizer	32	3.96	2.71,5.25	32	93.51	83.33,99.09
Sinovac	54	6.38	4.78,7.95	53	94.64	85.98,99.51
Sputnik V	155	18.36	15.82,21.15	155	98.30	95.79,99.88
Unspecified	113	13.39	11.16,15.63	110	96.87	92.92,99.39
No	13	1.74	0.91,2.70	11	81.15	62.14,94.97

95%CI: 95% Credible Intervals
* Estimation assuming each percent is distributed Beta with a standard uniform prior. For small sample sizes, the prior is strong enough that the posterior estimate does not move far enough from 0.5

Convenience sample

Supplementary tables 2-4[25] show the results for the convenience sample. Briefly, *n*= 575 Cycle 1, *n*= 456 Cycle 2, *n*= 893 Cycle 3, and *n*= 637 Cycle 4 workers were included. Sex distribution was similar to the random sample, with slightly more women in Cycles 3 and 4. The percentage of positive PCR tests was higher than in the random sample of individuals with antibodies. Workers with an RD-STDC in the previous six months were Cycle 1: 12.55%, Cycle 2: 8.70%, Cycle 3: 9.61%, and Cycle 4: 9.92%. Seroprevalence across different factors and vaccination status was similar to the random sample.

Discussion

In this study of workers from a large-scale essential company in the GMCMA, we found that the workforce was largely dominated by men and that most were younger than 50. This translated into an important time lag between the start of the pandemic in Mexico and vaccine eligibility for this population group; workers 40-49 were vaccinated May-June 2021 and those younger from June 2021 onward. The first three cycles were well before the vaccination campaign, and we detected that at least 20% of workers had antibodies, indicating previous infection with SARS-CoV-2. The seroprevalence for our first cycle was similar to that reported in the 2020 Covid-National Health and Nutrition Survey (28%; 95%CI: 25.6,30.4).[27]

When analyzing the data for the first three cycles simultaneously in the multilevel logistic regression models (accounting for dependency of time, strata hierarchy and survey's sampling design) we confirmed a strong association between reporting an RD-STDC and seroprevalence with ORs of 6.44 (95%CI: 3.24,13.67), 7.28 (95%CI: 3.76,15.07), 5.72 (95%CI: 2.72,12.00) for cycles 1, 2 and 3 respectively. Interestingly the association is strongest for cycle 2 despite seroprevalence being lower than cycle 1 for both men and women (table I). In this same model we confirmed that men had higher odds of being seroprevalent compared to women and that cycle 3 had a stronger impact OR= 6.66 (95%CI: 2.58,26.82) and workers between 45-59 years old showed a stronger association in cycles 1 and 2, contrary to these workers older than sixty showed a protective association with odds lower than 1, however this is not surprising due to the small number of workers in this age group that were included in the study (since per the Health Ministry mandate they should've been working remotely). Lastly, having Covid-19 symptoms had the strongest association with seroprevalence for the first cycle OR= 7.51 (95%CI: 4.24,14.02), this is interesting since the data is self-reported and could be pointing at a reporting bias as the pandemic in Mexico was more recent and less information on associated symptoms was available possibly leading to workers over report symptoms compared to the following cycles, or conversely there was less symptom reporting in the following cycles. Overall, we saw that having an RD-STDC in the previous six months was strongly associated with seroprevalence and highlights the usefulness of administrative data readily available to predict disease in a defined population.

During Cycle 1, the first epidemic wave was declining. Official data reported close to 750 000 confirmed cases, with a daily incidence that varied from 1 806 on September 27th to 6 254 on the 28th, with an average of 4 911 new cases per day.[28] Given our sampling change on Cycles 2 and 3, we can only readily compare results for Cycle 1, which points to a possible larger seropositivity in this workforce.

Essential workers have been reported to have activities with prolonged close contact associated with more vulnerability to Covid-19.[29] A study of meatpacking workers identified the use of public and shared transportation, crowded living conditions, and poor physical distance during breaks-common in our study population.[30] Additionally, activities related to production, transportation, food preparation, and sales had been identified as Covid-risk activities.[31] Cases among health care workers showed a nonlinear growth across the Covid-19 waves; a study in Italy showed an increase in total cases in the second wave and a considerable reduction of total cases during the third wave that could be due to the vaccination strategy.[32] Considering that IgG persistence over time is influenced by the severity of Covid-19, that they can decline by 31.3% by after 3 months[33] but could remain up to 430 days after infection,[34] our results suggest that a large proportion of workers had subclinical infection (i.e. neither reported a history of respiratory illness nor sought out an RD-STDC) but developed antibodies, pointing to the need to reinforce and enable large-scale testing in asymptomatic individuals in an active workforce to curb transmission. To our knowledge this is the only study that has evaluated the presence of antibodies in Mexican essential workers previous to vaccination and found that in cycle 1 (September 22-29, 2020) more than a quarter of male workers- 28.51% of men (95%CI: 24.59,32.21) and 20.85% of women (95%CI: 11.09,30.00)- had been infected; by cycle 2 (November 9-13, 2020) 22.18% of men (95%CI: 18.54,25.30) and 16.85% of women (95%CI: 10.88,24.74)- workers had been infected; and by cycle 3 (January 4-9, 2021) 21.26% of men (95%CI: 17.38,25.20) and 16.93% of women (95%CI: 8.30,25.80)- workers had been infected. A study of seroprevalence to SARS-CoV-2 in n=262 public transportation workers in Sweden (April-May 2021) found a 50% seroprevalence, which was more than twice than the general population (18.3%). The same study also found that men had higher risk of being seropositive (OR 1.3, 95%CI: 1.1,1.6) in line with our study.[10] Given no sex difference for Covid-19 infection,[35] we infer that this could be due to the sex disparity in economic employment in Mexico, with more men than women being formally employed.[36] However, men tend to have higher mortality rates.[37] Another seroprevalence study of n= 418 public servants from the municipality of Prishtina, Kosovo (October-November 2020), found that 21.1% of them tested positive,[11] similar to the seroprevalence in our study. In grocery store workers, another essential workforce during the pandemic, n= 706 grocery workers from Minnesota 7.9% were seropositive and having more job responsibilities increased the risk of being seropositive OR:1.14 (95%CI: 1.01,1.27).[12] Our study participants worked at a distribution center, a sales center or a production plant. We found a higher seroprevalence in production plants in the prevaccination cycles (i.e. cycles 1-3, results not shown) in line with these findings, as workers in production plants have more variation in their work tasks and are surrounded by more coworkers.

The results for the RD-STDC were somewhat unexpected; Cycle 2 was 3% lower than in the first cycle. However, this can be explained given the time elapsed between cycles and the RD-STDC correlation to the underlying epidemic behavior. A decrease in RD-STDCs could reflect low awareness to prevent transmission during work activities to avoid out-of-work virus spread; to encourage reporting, IMSS implemented a strategy to facilitate online RD-STDCs, avoiding having symptomatic people expose others when visiting hospitals and healthcare personnel. During the study period the company's RD-STDC translated to 43 million pesos from 119 210 authorized disability days and 86 848 subsidized days which means that 73% of authorized days were paid to the worker since there are two types of STDC, for a general illness (60% of salary paid from the 4th day onward) and for a work related illness (100% of salary paid from the 1st day). This loss of income for the worker, when on a STDC for general illness could explain that 21% in cycle 1, 18% in cycle 2, and 17% of workers that were seropositive didn't have a RD-STDC in the previous six months.

A limitation in our study was that we didn't have control over the sampling frame, so we were unable to adjust for information on eligible workers that varied between each cycle due to 1) new hires, 2) contract termination, 3) change of work center, or 4) new vulnerability determination. The company financed all biological testing and decided that study participants who tested positive should not be tested again, hence excluding them from the sampling frame in subsequent cycles. At the time of this study, we hadn't considered immunity waning either. Workers that tested positive for antibodies were excluded from the subsequent sampling frame. This could represent a bias in our estimations that can be considered a lower bound for the true prevalence, in other words our results are most likely underestimated. Another limitation was the analysis of anti-S antibodies for Cycle 4 (instead of anti-N), which impeded comparison with the previous cycles, however the results can indirectly be used to highlight the success of the vaccination campaign. The company financed all biological testing, hence made the corresponding decisions and their priority was vaccination compliance. We were able to report that only 1.74% of study participants were not vaccinated and Astra Zeneca vaccine was the most prevalent (52.48%).

The integration and use of RD-STDCs can be leveraged as a source of complementary data for health system surveillance. Our study is a private-public collaboration, and the results were analyzed and discussed with decision-makers of the company to mitigate transmission chains in work centers, maximize the impact of control measures (such as case identification and contact tracing), or otherwise optimize existing management and engineering measures established by the company during the pandemic.

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Declaration of conflict of interests. The authors declare that they have no conflict of interests.

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